

Defects in Ultra-Thin Resist Films

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Outline

I. Introduction

- A. Previous works in UTR defectivity
- B. SP1 tool & defect inspection
- C. CRS tool & defect inspection

II. Experimental Details

III. Results

IV. Conclusions

Instabilities responsible for the formation of dewetting and pinholes in films

Van der Waals intermolecular forces tend to amplify thermal fluctuations in the film -- spinodal dewetting

Substrate induced contamination or imperfections tend to form nucleated holes in the film

Marangoni instabilities -- temperature & concentration induced surface tension gradients -- responsible for the flow of the dewetting front and the associated hole growth and rupture within the film.

Challenge: How to minimize these forces to ensure stable, smooth, continuous, uniform and pinhole-free films.

Previous works in UTR defectivity

Previous workers reported pinhole defect levels scaling roughly as the inverse of the square of the film thickness

Kuan et al. J. Vac. Sci. Technol. B6(6), pp. 2274-2277 (1988)

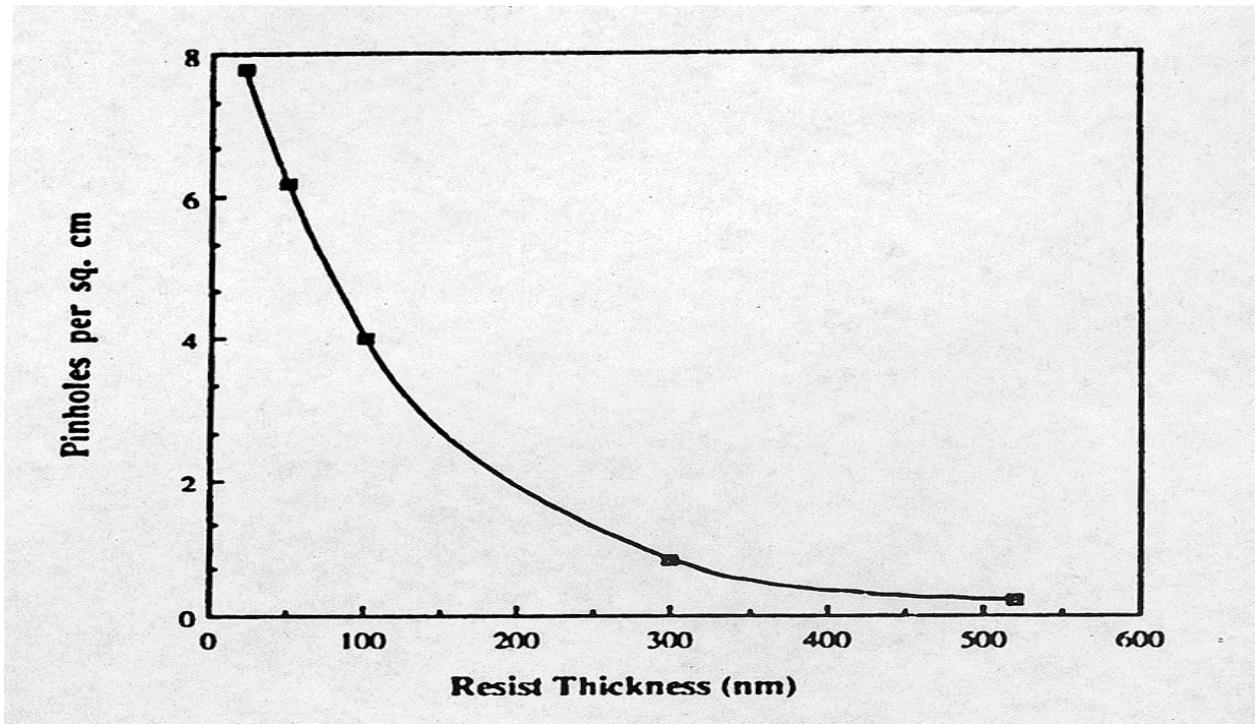
Early, et al. Soft-X-Ray Lithography Conference, Monterrey, CA (1992); Applied Optics 32(34) pp. 7044-7049 (1993)

Muller et al. J. Vac. Sci. Technol. B10, 2560 (1992)

Kunz, IEEE Lithography Workshop, Santa Fe, NM (1992)

Previous works in UTR defectivity

**Pinhole density in 80-nm chromium films after 60-s etching
masked by spin-cast AZ 5206 resist films of various thickness**



Kuan *et al.* J. Vac. Sci. Technol. B6(6), pp. 2274-2277 (1988)

Previous works in UTR defectivity

Pinhole densities of ultrathin polymer films

	L-B PMMA (10 wafers)	Spin-cast PMMA (5 wafers)	Spin-cast Novolac (5 wafers)
Film thickness	14.3 nm	14 nm	22 nm
Pinhole density	<10/cm ²	10 ⁴ /cm ²	<10/cm ²

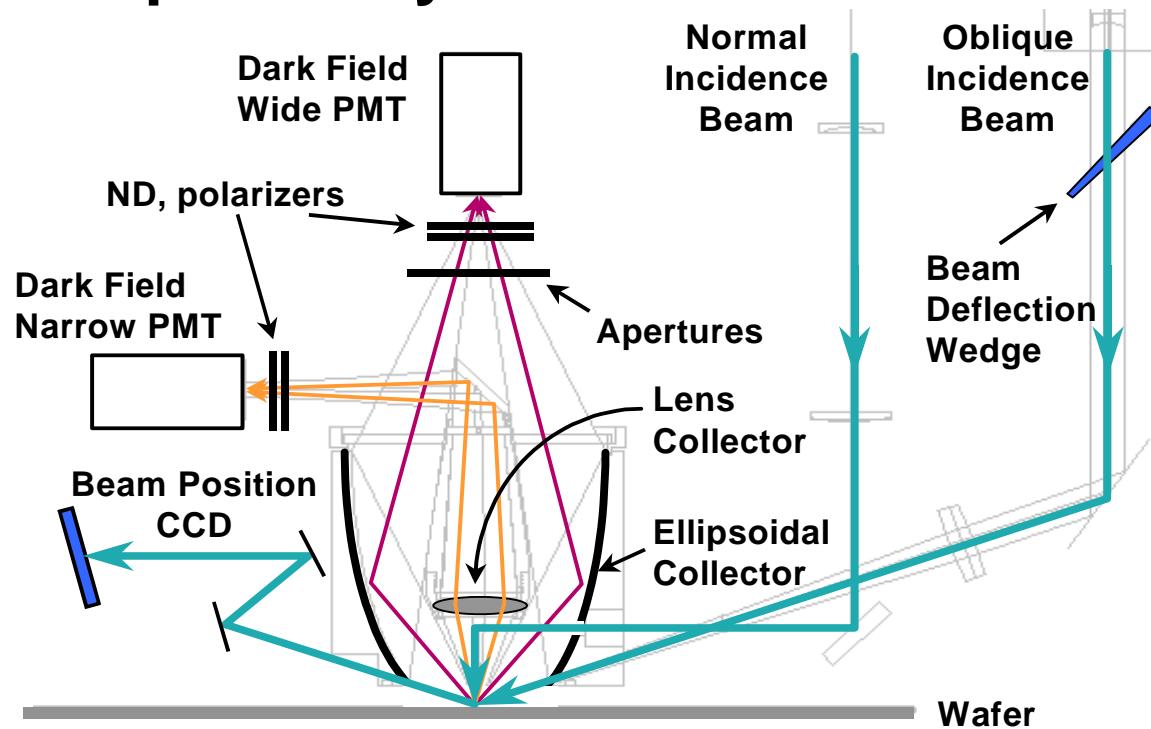
Kuan, *et al.* J. Vac. Sci. Technol. B6(6), pp. 2274-2277 (1988)

<u>Thickness (nm)</u>	<u>Pinholes (cm²)</u>
380	0.2
250	1
100	4
50	15

Early, *et al.* Soft-X-Ray Lithography Conference, Monterrey, CA (1992);
Applied Optics 32(34) pp. 7044-7049 (1993)

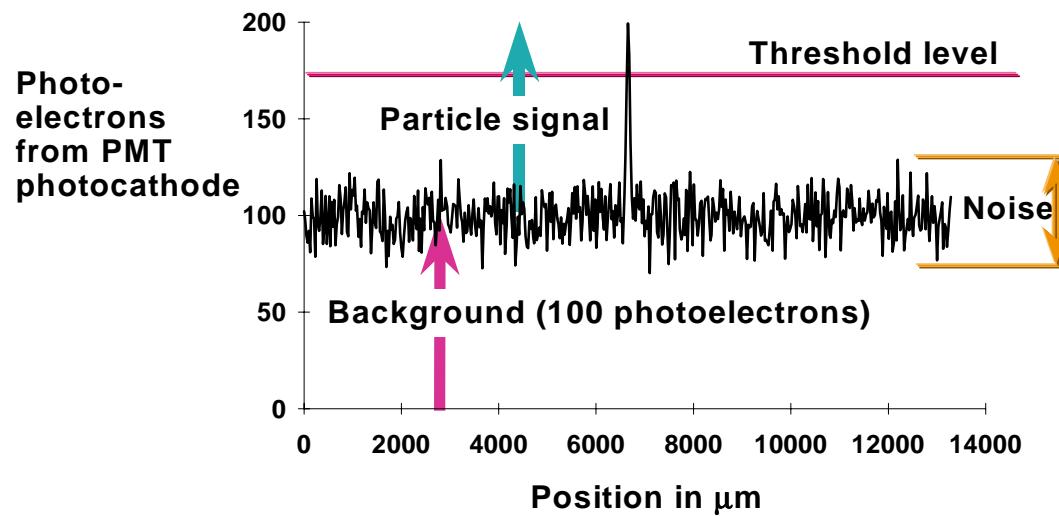
SP1 tool & defect inspection

TBI Optics Layout



What is defect and what is noise?

Surface scattering (haze) limits ability to detect particles on unpatterned wafers.

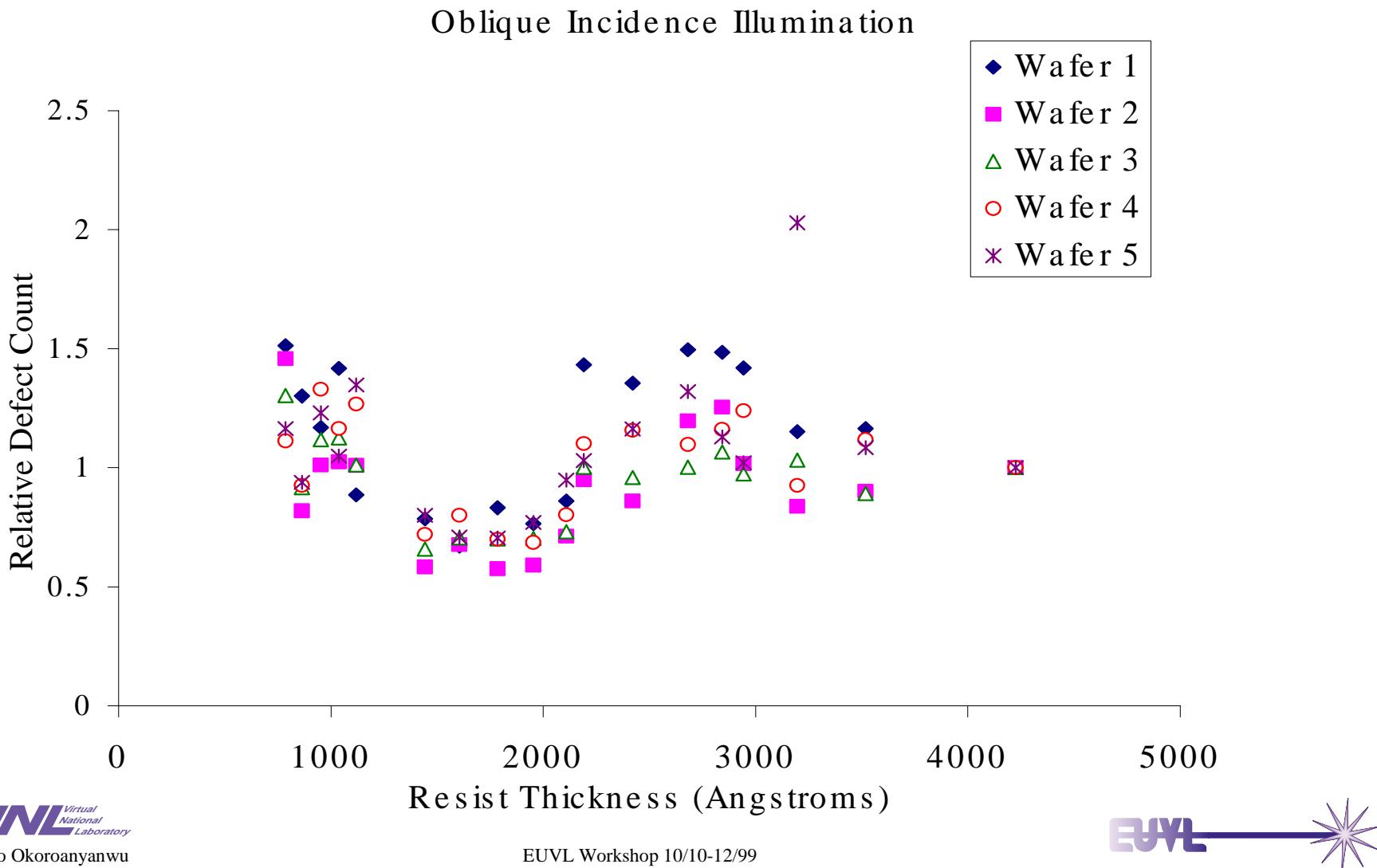


Experimental Details

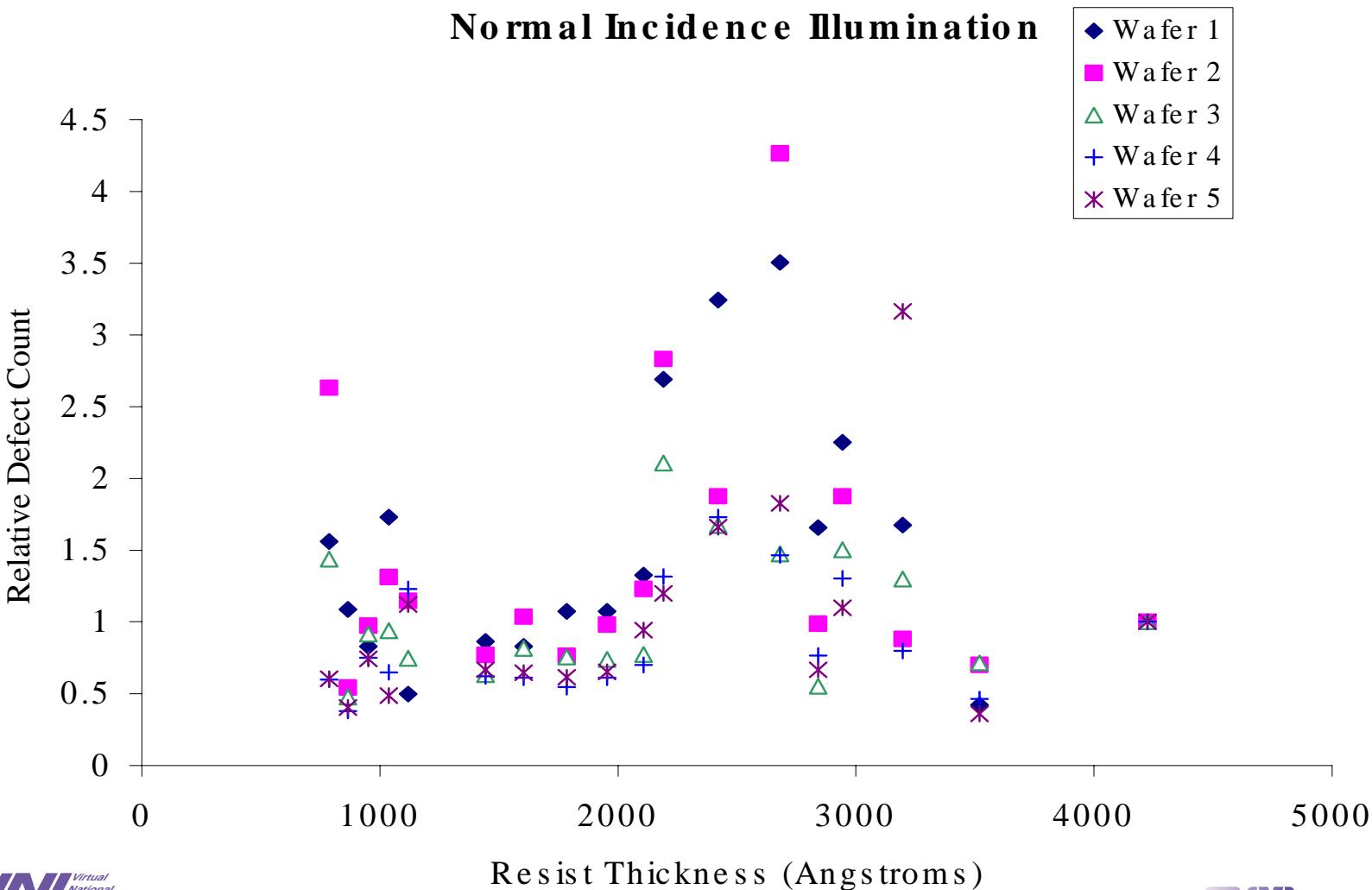
<i>Kinem atic Viscos ity (m m²/sec.)</i>	<i>Spin Speeds (rp m)</i>	<i>Number of Wafers Coated</i>
4.61	1000	5
	2000	5
	3000	5 [25]
	4000	5
	5000	5
5.96	1000	5
	2000	5
	3000	5 [25]
	4000	5
	5000	5
7.63	1000	5
	2000	5
	3000	5 [25]
	4000	5
	5000	5
9.36	1000	5
	3000	15
	5000	5

Tools: TEL Mark-8 Track, SP1/TBI (calibrated with PSL), CRS, SEM tools

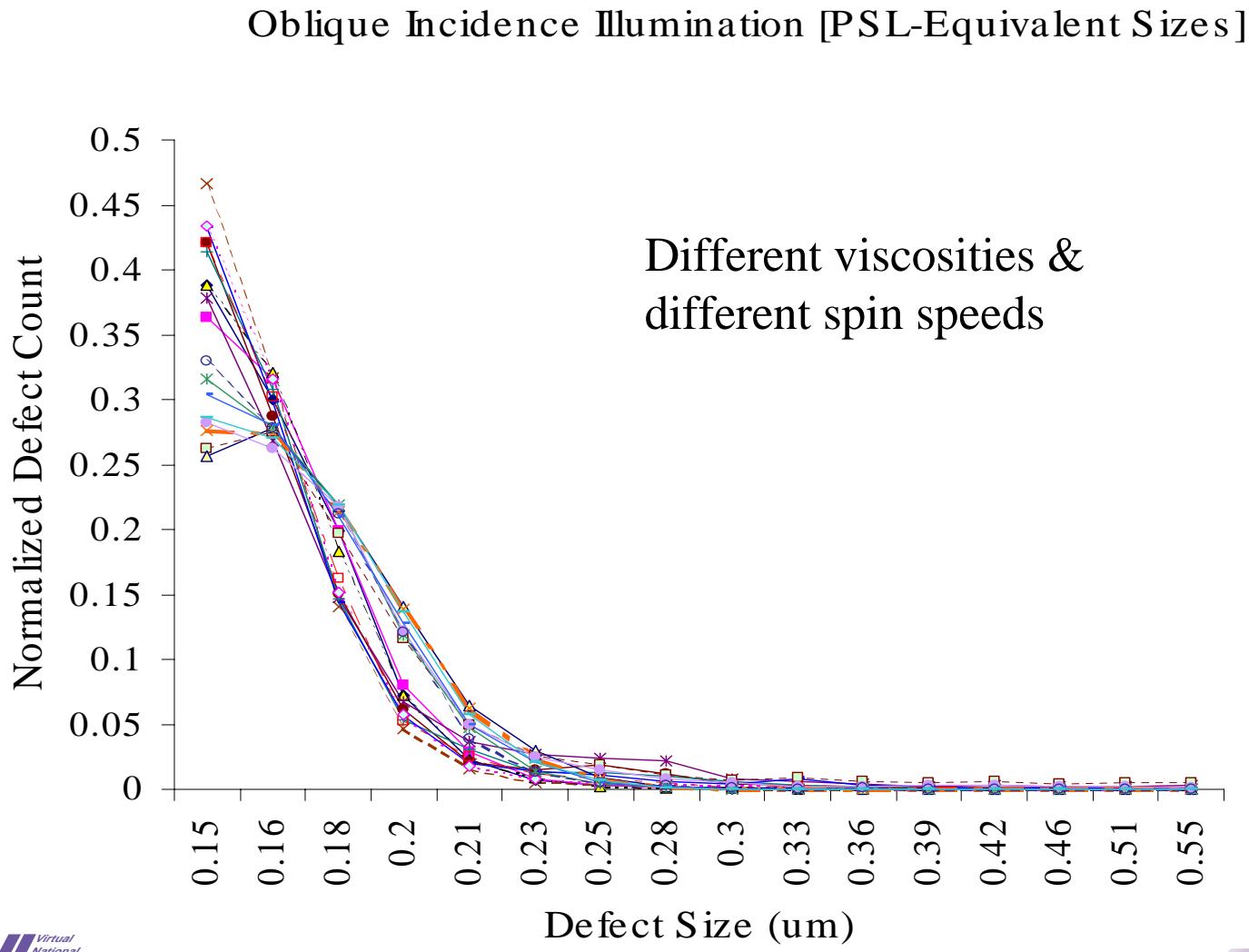
Relative defect count vs. resist thickness as measured at oblique incidence of the SP1/TBI



Relative defect count vs. resist thickness as measured at normal incidence of the SP1/TBI

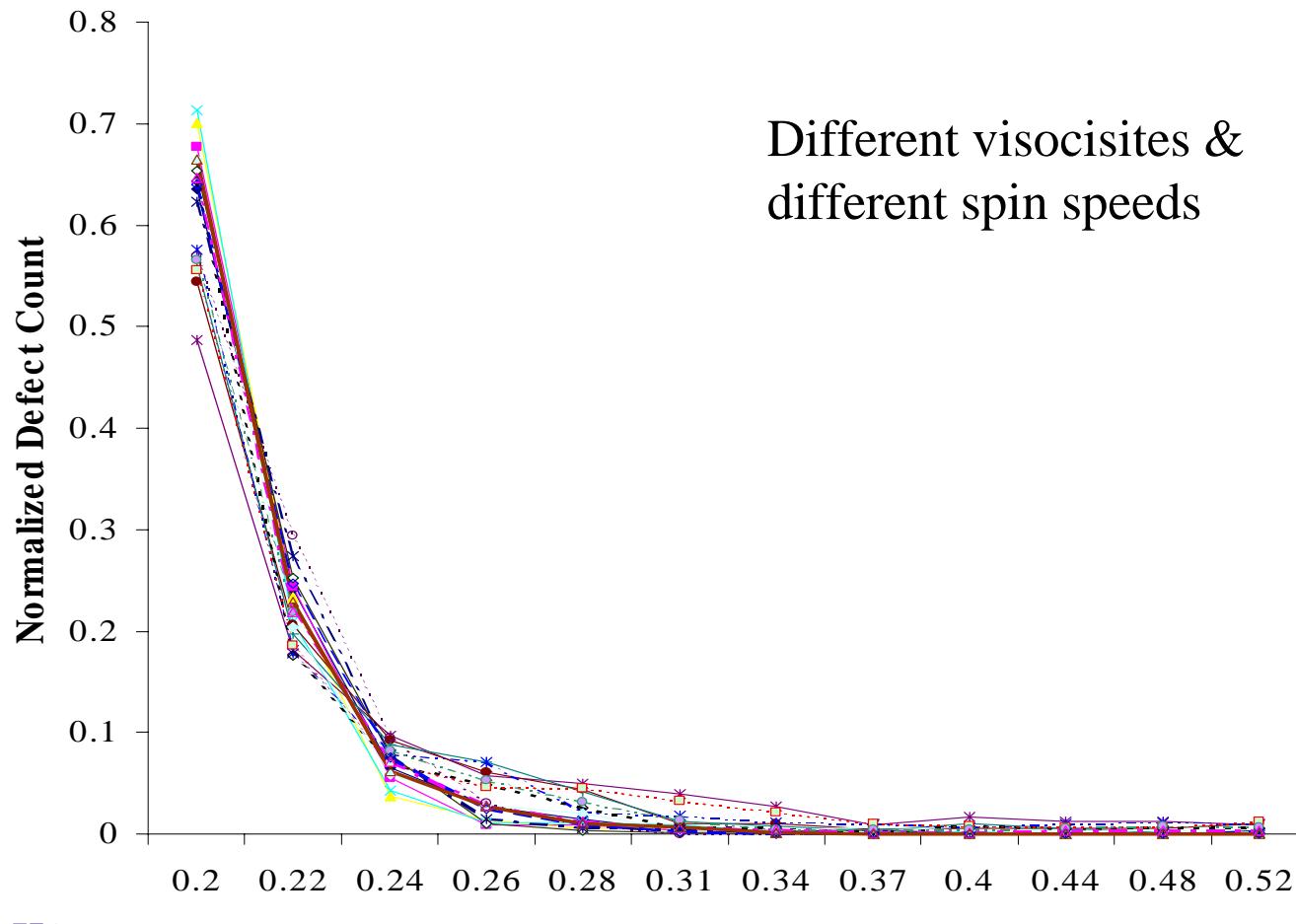


Normalized defect count vs. size distribution plot as measured at oblique incidence of the SP1/TBI



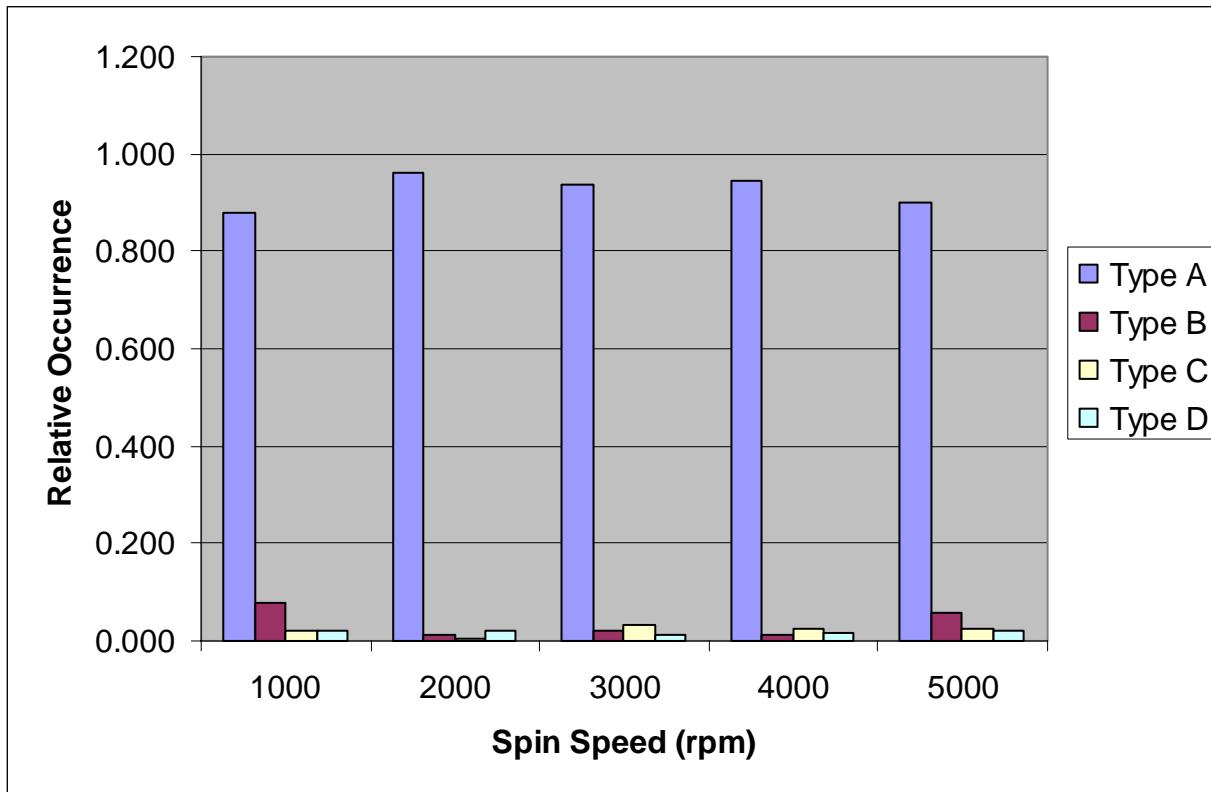
Normalized defect count vs. size distribution plot as measured at normal incidence of the SP1/TBI

Normal Incidence Illumination [PSL-Equivalent Sizes]



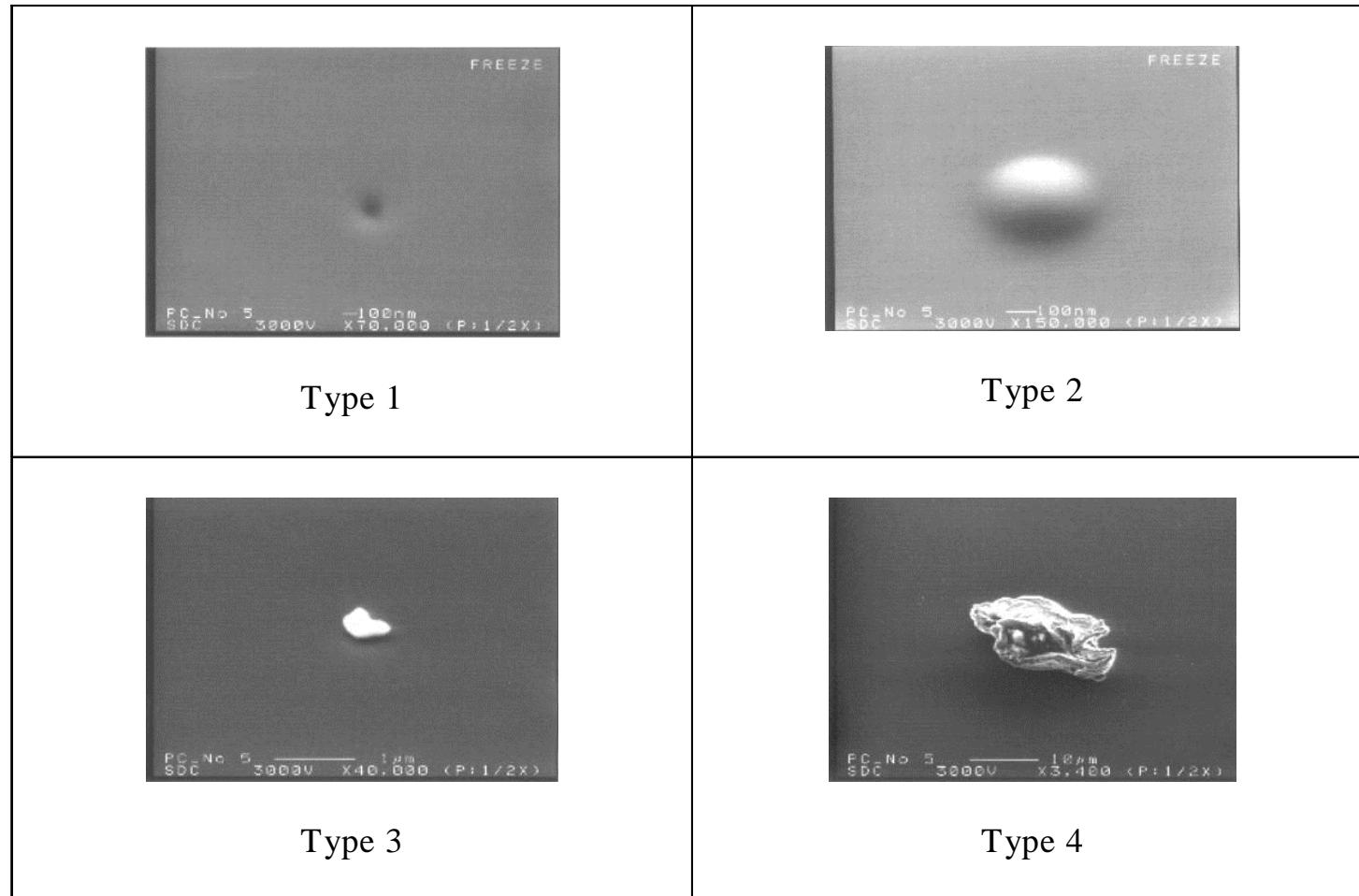
Different viscosities &
different spin speeds

CRS Review: defect classes identified in lowest viscosity resist [786-1119 A]



- Type A: Typical size 0.2-0.3 μm ; not able to discern pinhole vs. particle
- Type B: Typical size 0.7-2.0 μm , almost all particles.
- Type C: Bubble-like defects in a 3-5 μm cluster; individual defects not resolved.
- Type D: Particles > 5 μm (likely fall-on).

SEM review: 4 defect classes identified in lowest viscosity resist [786-1119 Å]



SEM Defect Review Summary

Viscosity	Spin Speed	Type 1	Type 2	Type 3	Type 4	Type 5
[cS]	[RPM]	[%]	[%]	[%]	[%]	[%]
4.61 cS	4000	90	6	2	2	0
4.61 cS	3000	86	4	2	2	2
4.61 cS	2000	88	6	4	2	0
9.36 cS	3000	0	8	34	50	8

Defect Type Definitions

Type 1: “Dimples” [Crystal originated pits (COPs)]

Type 2: Bubbles

Type 3: Particles < 1.0 um

Type 4: “Fall-on” particles > 1.0 um

Type 5: Other

Conclusions

- I. Quantified & reviewed UTR defects with optical and SEM metrology tools, respectively, and compared UTR defect densities and types with 0.4 μm baseline process
- II. For a well optimized coating process, no discernible dependence of defectivity (in densities and size distributions) on spin speed and film thickness (0.08-0.4 μm) of resists studied.
- III. Coat process-induced pinholes appear not to be significant.
- IV. Majority of observed defects are “COPs”